Segmental Liver Resection Using Ultrasound-Guided Selective Portal Venous Occlusion

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Anatomical segmental resection of small hepatic lesions using operative ultrasonography is improved by selective intrahepatic portal venous occlusion. The technique was successfully performed in 15 of the 18 patients in whom it was attempted. The lesions resected included 7 hepatocellular carcinomas in cirrhotic patients, 5 hepatic metastases, 2 benign tumors and 1 gallbladder carcinoma. The mean duration of local vascular exclusion was 47 minutes (range, 22 to 80 minutes) and mean blood transfusion requirement was 1.3 units (range, 0 to 7 units). Five patients sustained postoperative complications and these included chest infection (2 patients), ascites (2 patients), pleural effusion (1 patient) and hemorrhage (1 patient) from the site of hepatic resection. There were no postoperative deaths. One patient required further resection of a recurrent colonic metastasis and two patients have died of disseminated disease. This technique has allowed limited anatomical resection of lesions that would have otherwise required extensive classical hepatic resections or would have not been amenable to resection.

IMPROVED METHODS OF MORPHOLOGICAL investigation now allow detection of hepatic lesions at an early stage. Increasing experience with abdominal ultrasonography has permitted the detection of small hepatocarcinomas in at-risk patients although these lesions are located in an irregular cirrhotic liver.[1] Classical techniques of hepatic resection may be inappropriate for such small lesions in that an excessive amount of functioning parenchyma may be needlessly sacrificed, a sacrifice that can have dire consequences in patients with compromised liver function. Furthermore, hemostasis may not be achieved easily following simple wedge resection and the use of hilar clamping to facilitate resection may precipitate liver failure.[2] Segmental or subsegmental resection based on the portal venous anatomy may reduce these risks and may also reduce the risk of local tumor recurrence because hepatocellular carcinoma is thought to disseminate locally by the portal route.[3] Liver resection using selective portal venous occlusion with a balloon catheter, as described by Shimamura and his colleagues,[4] may facilitate segmental or subsegmental resection. We present our experience using this technique in segmental liver resection and discuss its possible indications.

Patients and Methods

Patients with lesions suitable for segmental or subsegmental resection were selected on the basis of preoperative investigations that included abdominal ultrasonography, CT scanning, and selective celiac and mesenteric angiography with portal venous-phase imaging. Lesions smaller than 6 cm and localized to one or two segments (Fig. 1)[5] were considered for resection. Preoperative percutaneous biopsy of hepatic lesions was not undertaken but a diagnosis was made on the clinical presentation and radiological investigations. Patients with suspected malignant hepatic lesions underwent preoperative assessment that included thoracic and abdominal CT scanning, isotope bone scan, and colonoscopy when appropriate.

Suitability for resection was further assessed by peroperative ultrasonography. The lesion was accurately localized with regard to the segmental anatomy of the liver by identifying its relationship to the hepatic veins and portal venous segmental branches. Ultrasound- guided biopsy was undertaken with a Meninghi needle (Hepafix, Braun, Melsungen, Germany). The absence of other hepatic lesions was confirmed by ultrasound and guided biopsy undertaken as appropriate.

Once the decision to undertake resection was made, the corresponding branch of the hepatic artery was dissected in the liver pedicle. The portal branch corresponding to the segment to be resected was identified by ultra-

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sonography and was punctured in its longitudinal axis with a 22-gauge Chiba needle. Its position in the vein was confirmed by ultrasonography and by aspiration of venous blood on withdrawal of the stilette. A flexible guidewire was passed down to the portal vein. Following withdrawal of the cholangiography needle, a dilator, and an introducing catheter (Vascular Introducer System, 5 French Gauge Cordis Corporation, Miami, Florida) were placed in the portal venous branch. A balloon catheter (5 French Gauge, 65 cm, Biotrol Pharma, Paris, France) was then passed through the seal of the introducer catheter. The balloon was inflated with up to 1 ml of isotonic saline and was positioned under ultrasound guidance to occlude the portal segmental vein. The inflated balloon is readily identified on ultrasound examination because of the presence of tiny microbubbles in the saline that appear as small hyperechoic areas. The arterial branch was then clamped to delineate the segment to be excised (Fig. 2). The segment was further outlined by injecting methylene blue dye in the side port of the introducing catheter.

Resection of the segment was undertaken by first incising the liver capsule with a diathermy point. Dissection of the liver parenchyma was undertaken using an ultrasound dissector (Cavitron Surgical Systems, Stanford, Connecticut). Small vessels were coagulated with diathermy and the more substantial vessels were ligated with fine silk ties (4/0) and divided. In those circumstances in which a bisegmental resection was undertaken, the arterial and portal blood supply to segment IV was first isolated to the right of the falciform ligament and the segment was resected as previously described.[6,7] Once the resection had been completed, the hepatic arterial branch was unclamped, the balloon was deflated and further hemostasis was secured by diathermy or suture ligation with 4/0 silk. The balloon and introducer catheter were then removed and the resultant entry point was sutured with 4/0 silk.

The duration of localized vascular exclusion and the operative blood transfusion requirements were noted. Serum bilirubin, aspartate aminotransferase (AST), alanine aminotransferase (ALT), and prothrombin time were measured on the day before surgery and on days 1, 3, 7, and 14 following resection. The results are expressed as mean ± 1 standard error.

Results

Between July 1984 and March 1988, segmental or subsegmental resection was attempted on 18 patients with this technique on a total of 46 patients who had segmented resections. In three patients, localized vascular exclusion could not be achieved. In the first of these patients, cannulation of the portal venous branch was unsuccessful due to the small size of the vein and the increased arterial blood supply resulting from a previous portacaval anastomosis. In a second patient who had a hepatocellular carcinoma, satisfactory occlusion was not obtained, although methylene blue was successfully injected into the portal venous segment and clearly identified the relevant segments. In the third patient who had a recurrent adenoma, the technique was compromised by distortion of the local anatomy secondary to a previous wedge resection.

Details of the 15 remaining patients are given in Table 1. There were 10 men and 5 women with a mean age of 58 years (range, 38 to 70 years). The mean size of the hepatic lesions was 3.8 cm (1.5 cm to 5.6 cm) and in all patients undergoing resection for metastatic disease, the primary tumor was colorectal in origin, except for patient 12 who had previously undergone resection of a liposarcoma. In 11 patients only 1 segment was excised, while in the remaining 4 patients resection was associated with excision of all or the anterior portion of segment IV. The mean duration of local exclusion was 47 minutes (range,

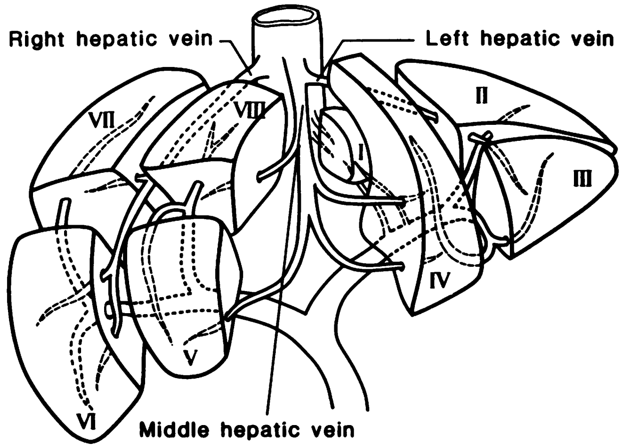
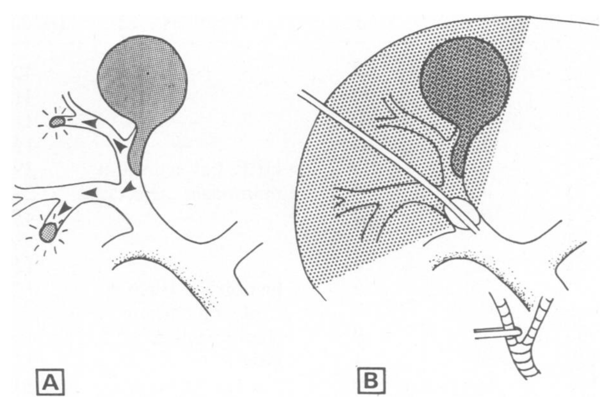


FIG. 1. Diagrammatic representation of segmental anatomy of the liver. The eight segments (numbered individually in Roman numerals) are based on their own portal venous blood supply (reference 5).



FIGS. 2A and B. (A) Diagrammatic representation of local dissemination of hepatocellular carcinoma by the portal venous route. (B) Diagrammatic representation of localized segmental vascular exclusion. Selective arterial clamping and inflation of a balloon catheter in the portal segmental branch has delineated the hepatic segment (shaded area) to be resected. See text for detailed explanation.

TABLE 1. *Patient Details Undergoing Hepatic Resection Under Selective Vascular Occlusion*

Patient Number	Age	Sex	Size of Lesion	Segment	Diagnosis
1	68	M	2.5	V	FNH
2	38	F	5.0	V + IV	HA
3	68	M	4.5	IV + VIII	HCC
4	60	M	2.5	V	HCC
5	56	F	1.5	V	HCC
6	50	F	5.0	V + IV	Met
7	70	M	3.0	VIII	Met
8	60	F	5.6	V + IV	GB
9	57	M	2.0	V	HCC
10	58	M	2.5	VIII	Met
11	52	M	4.5	VIII	HCC
12	48	F	3.5	VIII	Met
13	50	M	4.5	V	HCC
14	67	M	5.0	VI	Met
15	69	M	3.5	VIII	HCC

FNH, fibronodular hyperplasia; HA, haemangioma; HCC, hepatocellular carcinoma and cirrhosis; Met, metastasis; GB, carcinoma of gallbladder.

22 to 80 minutes) with a mean blood transfusion requirement of 1.3 units (range, 0 to 7 units; Table 2). No transfusion was required in ten of the 15 patients.

There were no operative deaths and complications occurred in five patients. One patient who had successfully undergone segmental resection of a hepatocellular carcinoma without requiring transfusion (patient 9), required laparotomy for intra-abdominal hemorrhage eight hours following initial operation. This was due to hemorrhage at the site of the insertion of the balloon catheter. Hemostasis was secured and the patient's recovery was complicated only by the development of a small pleural effusion that settled on medical therapy. Two of the remaining patients undergoing segmental resection for hepatocellular carcinoma developed severe ascites after operation and one of them (patient 5) required insertion of a peritoneal jugular shunt. Two of the four patients undergoing resection for metastatic disease developed respiratory complications that settled with physiotherapy in one (patient 6) and physiotherapy and antibiotics in the other (patient 10).

TABLE 2. *Operative Details and Long-term Survival*

Patient Number	Duration of Exclusion (minutes)	Blood Transfusion (units)	Complications	Survival (months)
1	60	2	—	42
2	60	0	—	41
3	80	0	—	11
4	40	3	—	15
5	22	7	HRF, LeVeen shunt	29
6	45	0	pulmonary atelectasis	29
7	60	0	—	44 (rec 5)
8	60	4	—	12*
9	35	0	hemorrhage right pleural effusion	15
10	50	0	chest infection	45
11	45	3	HRF	27
12	35	0	—	20*
13	40	0	—	12 (rec 5)
14	35	0	—	8
15	40	0	—	8

* Survival ended by death.
HRF, hepatorenal failure; rec, recurrence.

TABLE 3. *Changes in Liver Function Tests in Five Cirrhotic Patients Undergoing Resection*

Test (normal values)	Day 0	1	3	7	14
Serum bilirubin 0–17 umol/l	27.3 (4.2)	54.6 (5.1)	52.8 (8.9)	47.9 (9.2)	44.6 (6.5)
AST <28 u/l	61.2 (15.0)	130.6 (27.3)	158.8 (39.9)	53.6 (8.5)	43.5 (8.1)
ALT <35 u/l	27.7 (12.4)	91.6 (23.5)	147.8 (47.0)	62.8 (12.7)	30.8 (10.1)
Prothrombin 70–130%	66.2 (11.7)	69.0 (8.6)	67.0 (7.8)	68.4 (8.6)	64.8 (9.7)

Values expressed as mean ± standard error.

There were no major abnormalities in liver function tests in patients with normal preoperative liver function. Table 3 shows the changes in liver function for the seven cirrhotic patients undergoing resection of hepatocellular carcinoma. The transaminase levels peaked at day 3 but returned to preoperative values by day 14. The prothrombin index remained constant after surgery.

Long-term survival of the 15 patients is shown in Table 2. One patient (patient 7), who had undergone segmentectomy (VIII) for colorectal metastases, developed a local recurrence and required a bisegmentectomy (VI/VII) 5 months after the initial procedure. This patient was still alive at 44 months without evidence of hepatic recurrence although there was evidence of pelvic recurrence on CT scanning. Another patient (patient 13), who had undergone a segmentectomy (V) for a hepatocellular carcinoma, was shown on ultrasound examination to have developed tumor in segment VIII. This was confirmed on ultrasound-guided percutaneous biopsy and the patient has been treated with systemic chemotherapy and is still alive at 12 months. Two patients have died with dissemination of tumor. Patient 8 died at 12 months and at postmortem examination was found to have pulmonary and hepatic metastases. Patient 12 died 20 months after hepatic resection and had peritoneal, hepatic, and pulmonary metastases.

Discussion

Compromised preoperative liver function may prevent resection of certain hepatic lesions because of the risk of precipitating postoperative liver failure. Although operative mortality rates of less than 5% have been reported for cirrhotic patients undergoing hepatic resections,[8] the hospital mortality rate in some recent Japanese reports is 17% to 19%.[9,10] In our own experience,[6] the hospital mortality rate was 12.2% in 41 cirrhotic patients undergoing resections for hepatocellular carcinoma compared to 4.1% in 49 noncirrhotic patients. Nagao and colleagues[10] demonstrated that the volume of operative blood loss was the most decisive factor in determining short-term prognosis in cirrhotic patients undergoing hepatic resection. However, temporary vascular exclusion of the liver is poorly tolerated in such patients[2,11] although in a review of their 3-year experience, Nagasue et al.[11] showed a reduction in hospital mortality rate from 23.5% with no hepatic vascular control to 10.5% when temporary clamping of the porta hepatis was employed. These workers had no hospital deaths in 11 patients undergoing resection during simultaneous occlusion of hepatic inflow and outflow.[11]

Shimamura et al.[4] have shown that a variety of hepatic lesions can be removed successfully with adequate vascular control and they reported an operative mortality rate of 8.6%. These workers maintained segmental vascular exclusion by a balloon catheter inflated in the portal venous segmental branch for periods of up to 15 minutes. We have not found it necessary to release the balloon in this way and one cirrhotic patient withstood localized vascular exclusion for 80 minutes without apparent complication. Nonetheless, all of our cirrhotic patients demonstrated abnormal liver function in tests after surgery and two patients required intensive treatment for ascites. The prothrombin index altered little in the postoperative period but changes may have been masked by transfusion of fresh frozen plasma during and immediately after surgery. The risk of postoperative liver failure is greatest in cirrhotic patients and this risk is directly proportional to the severity of the liver disease and the extent of liver parenchyma excision.[1] The technique of anatomical segmentectomy vascular exclusion has enabled resection of small hepatocellular carcinoma that would have otherwise required resection by right hepatectomy. Such major hepatic resections have been reported to be associated with a 60% operative mortality rate in such patients.[2] The use of this technique in hepatic resection in the noncirrhotic patient appears justified when the alternative would involve a more extensive classical hepatic resection or a localized resection with unsatisfactory vascular control. The main advantage of selective vascular exclusion is that it identifies clearly the anatomical segmental boundaries and minimizes the amount of devitalized hepatic parenchyma. It controls the bleeding and decreases the blood transfusions. Only two of the eight noncirrhotic patients required transfusion during or after surgery. It is noteworthy that there were no cases of intra-abdominal sepsis or collection at the site of resection in the present series.

Because spread of hepatocellular carcinoma may occur by the portal route,[3] it is desirable that the lesion is removed along with the involved portal venous bifurcation (Fig. 2). This resection is greatly facilitated and most readily achieved by occluding the portal venous branches. Our early results suggest that such resection for hepatocellular carcinoma may reduce the risk of local recurrence, although longer follow-up is required to determine whether these theoretical considerations are important. However, there is clear evidence from others[10] that recurrence is twice as likely after local excision of small hepatocellular carcinoma than after segmental resection.

Peroperative ultrasonography has an important role in the surgery of liver tumors and enables the surgeon to undertake more precise and limited resections than were previously possible.[12,13] These newer methods have undoubtedly improved the ability of surgeons to excise these tumors with a reduced risk as reflected in the increasing number of hepatic resections undertaken in our own institution in the last 14 years.[1]

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